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THE FORESTS OF THE FLATHEAD VALLEY, MONTANA.

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY. LXVII.

HARRY N. WHITFORD.

(WITH MAP AND TWENTY-THREE FIGURES)

[*Continued from p. 122.*]

II. EDAPHIC FORMATIONS IN FLATHEAD VALLEY.

IN the previous pages an attempt was made to show why the west side of the valley contains a prairie formation, and the east side a forest formation, and why the coniferous type of forest prevails rather than a broad-leaved deciduous type. A plot will now be presented in detail to show why in the forest formation there are some areas altogether without trees. In order to reach definite conclusions, a limited area was selected to represent the whole forest area of the valley. This area, comprising about 250 square kilometers, was mapped, and the conditions for forest growth were determined (*map*). The relation of this area to the whole valley is shown in *fig. 3.* It lies at the northeast end of Flathead Lake, and includes a portion of the main valley on the east side of the Flathead River at the head of the lake, the low end of the Mission Range of mountains, and a portion of Swan valley. In this area are found many types of topographic diversity, from Flathead Lake (890^{m}) to the highest point (about 1372^{m}) in that part of the Mission Range which is included in the map. No detailed study was made in the higher Swan Range east of the valley, though some conditions of tree growth were noted in these mountains. As shown by the map, five distinct edaphic formations were found: meadow (*hydrophytic*), Engelmann spruce (*meso-hydrophytic*), western larch-Douglas spruce (*mesophytic*), Douglas spruce-bull pine (*meso-xerophytic*), and prairie (*xerophytic*).

THE MEADOW FORMATIONS (HYDROPHYTIC).

As already mentioned, Swan valley was formerly a lake, the present condition being only a stage in its recession. The drainage consists of Swan Lake, Big Fork River, and a number of small streams; also one large pond known as Ross (Mud) Lake, which, with its outlet Ross Creek and the numerous small inlets, comprise the drainage of the extreme north end of the valley.

The most noteworthy fact about the hydrophytic vegetation is its resemblance to that found in similar edaphic situations in the eastern United States, both types of swamps being found here. Near the head of Ross Lake is a sphagnum meadow, in which *Menyanthes trifoliata*, *Drosera rotundifolia*, *Comarum palustre*, *Eriophorum polystachyon*, and *Betula pumila* are characteristic. At least two other large meadows show this combination. One of these is along Little Bear Creek, and is known as the School Meadow; another is found along Flathead River, and will be discussed in connection with the spruce forest which lies close to it. Ross Lake (*fig. 9*) is a pond which shows very well the zonal distribution of plants, being shallow and with a very muddy bottom. In its center and in streams bordering it are found the following characteristic species: *Nymphaea advena*, *Brasenia purpurea*, four species of Potamogeton, Myriophyllum, and Hippuris. The sedge zone bordering the water of the shallow ponds and streams contains the following species: *Bromus Richardsonii pallida*, *Muhlenbergia racemosa*, *Carex utriculata*, *C. viridula*, *C. hystricina*, *Calamagrostis caespitosa*, *Phalaris arundinacea*, *Juncus Regelii*, *Scirpus lacustris occidentalis*, *Lobelia* sp., *Cicuta maculata*, *Solidago* sp., and *Dodecatheon* sp.

The meadows are usually submerged during the spring and early summer months, when the melting snow of the mountains to the east swells the streams, and brings the water level slightly above the surface. In the latter part of the summer and fall the underground water level is a little below the surface; and it is this condition of submergence and emergence that determines the meadows and excludes trees. Of course some of these meadows are never entirely submerged, but are always wet, with few exceptions being associated with streams. The largest meadows are found near the head of Ross Lake, at its foot on the east side, near the mouth of Wolf Creek, at the foot of Swan Range along Little Bear Creek, and in the large bend of the river just east of Swan River cañon.

The meadows are given brief mention here in connection with this forest study because they are genetically related to the spruce forests that usually border them. It is obvious that trees do not grow in them because the amount of moisture in the soil is too great. Some of the meadows have been artificially drained, others have been planted to timothy, and one in particular, in the northwestern corner of the area (*map*), has been drained and cultivated for a number of years, so that its former nature was discovered with difficulty. What has been done artificially is being done naturally, but more slowly. The detritus that is washed into the ponds and the vegetation that dies down from year to year are filling up these bodies of water, and are making the meadow condition possible. Again, the streams are cutting their channels deeper, thus lowering the underground water level at their borders, and this changes conditions that favor meadows and introduces those that make the forest possible. It is very probable that many areas now occupied by spruce and other forests were formerly occupied by meadows. Indeed, all stages of development towards this forest condition were noted, and will be discussed under the next head.

THE SPRUCE FORMATIONS (MESO-HYDROPHYTIC).

In many places species of Salix and *Alnus incana* encroach upon the meadows, sometimes forming dense breastworks around the grass areas, so that it is difficult for other trees to get a start. This is the case when the zones of underground water level are sharply and narrowly marked off. Usually, however, when the underground water level is at a fairly uniform distance below the surface for a rather broad area, as it is where the small streams spread out over a level extent of land, the willow-alder breastwork is absent. These situations are favorable for the advance of *Picea Engelmanni* into the meadows. The youngest trees are found on the hummocks in the meadows; nearer its borders are the older ones, though they are still scattered; these grade imperceptibly sometimes into dense forests of spruce, many of the trees reaching huge dimensions. Since this formation is found best developed on situations where the underground water level is a little farther below the surface than it is in the meadows, it may be called the meso-hydrophytic formation.

It must not be supposed that there are no other trees with the spruce; indeed there are only small tracts where pure spruce woods are found. The most common companion trees are *Populus angustifolia*, *Populus tremuloides*, and *Betula papyrifera*. These species nearly always form a small per cent. of the spruce forests, and in the meso-hydrophytic area along the Flathead River they occupy nearly the entire space. In Swan valley the soil is a mixture of clay and humus; along Flathead River, especially in the delta region, the subsoil is sand, overlaid by a fine alluvial deposit. In the dense woods the undergrowth is scanty, sometimes only one or two species being present, the most common plant associated with the pure spruce growths being *Rhamnus alnifolia*, although *Cornus stolonifera* is often found. In the narrow strip of this forest along the streams nearer the mountain *Echinopanax horridum* and *Veratrum californicum* are present. Since the spruce woods are transitional between the meadow and the mesophytic woods, the undergrowth of these associations is often present. Thus, near the meadow side of the forest, grass plots are frequently present, and on hummocks between anastomosing channels *Lysichiton kamtschatcensis* is frequent. On the other hand, toward the mesophytic side of the forest the elements of the undergrowth of the western larch-Douglas spruce formation are to be found.

An area of spruce is found in connection with a meadow in the northwestern corner of the plot not far from the Flathead River. Here on the border of the prairie formation is an area that has almost identically the same plants as the spruce forest in the Swan valley. Along the east side of this swamp there are numerous springs, some large enough to give rise to small streams, and others hardly noticeable. The source of the water supply is thought to be Echo Lake, which, with a number of smaller ones, lies in the depressions of a moraine that extends beyond the limits of the plot to the northeast. Save a small stream, there is no visible inlet to this lake, and its source of water supply is probably by underground seepage from the mountains that lie northeast. There is also no outlet above ground, and since the drainage is toward the Flathead River it is thought that the springs mentioned are fed by underground seepage from these lakes and ponds. This underground water level, as shown by the wells in the neighborhood, is in places nearly a hundred feet below the surface, and extends underneath the larch-Douglas spruce and bull pine forests and the prairie to a low ridge near the Flathead River, where it issues in the form of springs, making conditions favorable for an Engelmann spruce formation. Thus a bit of forest is projected, as it were, into the prairie formation. Where the water level comes nearer the surface the meadow already mentioned is associated with the forest.

Another meso-hydrophytic forest in which the spruce is almost entirely wanting needs to be mentioned. Around the head of Flathead Lake, including the delta at the mouth of the river (*figs. 1* and *4*), and extending up the river from its mouth, is a region that is annually submerged.[13] This region is occupied by a dense growth of willows, cottonwoods, birch, aspen, and other trees. On each side of the mouth of the river are long, low peninsulas of sand, the ends of which are entirely barren of vegetation. These are above water only a short time during the growing season, and this fact no doubt prevents plants from getting a start. A short distance back from the end of the delta on a little higher land is *Salix fluviatilis*, in some places so thick as to be almost impenetrable. Underground stems are sent out from this center, and thus new territory is gradually conquered, so that as fast as the delta is built out it is occupied by this pioneer willow, which prepares the way for changes that make it possible for higher forms to exist. When the water is high its contact with the willows causes a deposit of fine silt, so that the delta is gradually built higher and higher, making conditions favorable for the growth of such plants as the red dogwood, other species of willow, narrow-leaved cottonwood, paper birch, aspen, choke cherry, two species of hawthorn, and service berry.

Around the head of the lake there is a low terrace which is also submerged in the spring and early summer months. Instead of *Salix fluviatilis* there is a thicket of other willows; and on the lake side of this there are a few scattered specimens of *S. fluviatilis* and *S. amygdaloides*. On the land side of the willow thicket are the birch, cottonwood, and aspen; and here and there are found small patches or single specimens of the western larch, Engelmann spruce, Douglas spruce, and bull pine. None of these were noticed on the delta proper, and with the exception of the Engelmann spruce they seldom occupy the areas that are often submerged. Of course in the lowest places the meadow type of vegetation prevails, and elements of it are scattered more or less through the area occupied by the trees. As already shown, the lake formerly extended over the valley north of it, and as its waters receded it is very probable that vegetation similar to that found around its shores today occupied similar areas around the shore line of the former lake. Of course as the gradual lowering of the underground water level brings about unfavorable conditions for those plants that exist around the shores, these are replaced by those needing other conditions. On that portion of the shore line that borders the area where the rainfall is insufficient to support trees, the swampy areas will pass through the meadow, the cottonwood-birch-aspen type, to the prairie. However, if the shore line be in a region that has sufficient rainfall to support a forest, the first two stages will be followed by a western larch-Douglas spruce-bull pine stage.

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[13] During the spring and early summer months Flathead Lake and River rise some 4 to 6^m, submerging all the surrounding low country. In some instances excessive floods do great damage to the country lying at the head of the lake. Since nearly all streams in the valley have their sources in the mountains to the east, the deforestation of this region would greatly increase these spring floods and greater damage would be the result.

Since the Engelmann spruce is the most prevalent and the most important tree in the formation just described, its sylvicultural habits will be summarized. It has been shown that it does best in soils where the underground water level is not far below the surface, that is, for the plot under consideration, in low-lying lands bordering lakes, ponds, or streams. Thus it occurs not only in Swan valley, but also along the banks of Flathead River, where it is somewhat sparingly mixed with cottonwood-birch-aspen groups. It is the first tree to advance into the meadows. However, the Engelmann spruce is not confined to the more or less swampy region, for it is found scattered through the mesophytic areas in Swan valley. In the stands that lie adjacent to the spruce forests it is almost always present, and in some places it extends well out into the drier parts of the western larch-Douglas spruce formation, being found beyond the limits of the silver pine and lowland fir, and having a wider life range than either of these two species. It was often observed in the bull pine-Douglas spruce association where depressions in the topography brought the surface of the soil near the underground water level, and along streams. However, trees in these situations seldom reach large dimensions.

The Engelmann spruce can tolerate shade fairly well; in this respect it is different from western larch and Douglas spruce and is classed with silver pine and lowland fir. The fact that it can endure shade probably accounts for the presence of its seedlings in the forests that occupy the drier areas in the plot, for the forest canopy in these situations brings about a local climate that makes it possible for trees to exist that could not otherwise do so. The Engelmann spruce has the power of germinating in the open if there is sufficient soil moisture, and like the other shade-enduring species it does better in these situations than in the shade.

It will be seen from the foregoing that outside the semi-hydrophytic conditions Engelmann spruce does not flourish in the plot under discussion, being confined to the level stretches of land bordering on the meadows and open bodies of water. There is little doubt that as the waters of the former Swan Lake withdrew, meadows first occupied these areas and then were replaced by spruce stands. Just as the meadow conditions may be considered the first stage in the development toward the climax forest of the region, so the spruce forest may be considered the second stage. As the channel of Swan River is cut deeper the water level of the valley will be lowered, thus bringing about a condition favorable to the development of other types of forest which will replace the spruce association.

In the above account the distribution of the Engelmann spruce is discussed only in the area mapped. In the mountains bordering the area on the east it shows a wide altitudinal range, but is always associated with good moisture conditions, for it is found best developed in the damp cañons and on damp slopes where it is invariably associated with *Abies lasiocarpa*. In the high basins it does not do so well as the fir, but in the lower valleys it flourishes where the alpine fir does not.

THE WESTERN LARCH-DOUGLAS SPRUCE FORMATIONS (MESOPHYTIC).

In the discussion of the Engelmann spruce formation it was shown that on its borders and on the dry hummocks in stands of this tree other trees obtained a foothold. Just as there is a gradation from the meadows into the meso-hydrophytic forest in which the Engelmann spruce predominates, so there is a similar change from these into a forest in which the western larch and Douglas spruce are the principal trees. Again, this difference is due to a change in the underground water level; in the meadows it is near the surface; in the Engelmann spruce stands it is slightly below the surface; and in the western larch-Douglas spruce combinations it is still farther below. Indeed, in this association the water level is so far below the surface in places that the roots of the trees do not reach it, but rather depend on the water in the surface layers that comes from the rains or by capillarity from the underground water level. Since there is a medium condition of water in the soil, the forests occupying these areas are known as the mesophytic formations (*fig. 8*). Other trees found with *Larix occidentalis* and *Pseudotsuga taxifolia* are *Pinus Murrayana*, *Abies grandis*, *Pinus monticola*, *Picea Engelmanni*, *Thuja plicata*, and occasionally *Abies lasiocarpa*, *Pinus ponderosa*, and *Tsuga heterophylla;* also certain deciduous trees.

Associated closely with the spruce and almost invariably surrounding stands of it, except where the lodgepole pine is present, is found a forest in which the silver pine and lowland fir are at their best. Thus on the west side of the bay-like area of meso-hydrophytic forest west of Ross Lake, the spruce is gradually replaced by a magnificent growth of lowland fir, silver pine, western larch, and Douglas spruce. The lodgepole pine occupies a good deal of the spruce stands that would otherwise have developed into a forest like that just mentioned, were it not for the influence of fires. In various other areas are found forests in which silver pine and lowland fir form a more or less conspicuous element, especially in the area near the mouth of Meadow Creek. They are never unaccompanied by other species and seldom become the dominant trees, probably because the climate is not so congenial to them here as to some of the other dominant species.

The silver pine closely resembles its relative the eastern white pine. As already stated, in Flathead valley it does its best in the conditions surrounding the spruce stands, or where the water level is not far below the surface. However, it spreads over nearly all the mesophytic region in Swan River valley and ascends the east slope of the Mission Mountains in moist situations. In the swampy soils silver pine has a shallow root system and is easily blown over by winds, many large trees being observed lying prostrate with nearly the entire root system exposed. Where the soil has sufficient moisture, this tree can germinate in the open with no shade whatever, but it can pass the seedling stage in rather shaded conditions. The only two trees that have a shade too dense for it are the giant arborvitae and the western hemlock. While it can exist in the shade around the drier edges of the mesophytic forest, it fails utterly to maintain a stand in the mature growth of these areas, and except in extremely favored places the silver pine cannot be considered a successful tree for the region under consideration. It succumbs easily to fires, many instances being noted where fires had swept through the forests destroying the silver pine, while such trees as western larch and Douglas spruce were only slightly damaged.

The distribution of lowland fir is very much like that of silver pine, both reaching their climax growth in about the same situations. Where the water level is rather far from the surface it is more successful than silver pine in the low altitudes; but its altitudinal range is less than that of the latter. It is able to develop in open places, in soil so dry that silver pine is excluded. Where the moisture was sufficient it was not an uncommon thing to find stands of small (3 to 5^m high) trees so dense that absolutely all vegetation was lacking beneath them. It is more tolerant of the shade than is silver pine, and because it can grow in drier soils it extends as undergrowth into the borders of the meso-xerophytic regions, where silver pine is seldom if ever found. Like silver pine and Engelmann spruce, the range of this tree is extended because of the protection of the forest canopy, but this is not the region of its best development. The largest trees seen were less than a meter in diameter and not more than 38^m in height. SARGENT reports that it attains its best development along the Pacific coast in Washington, Oregon, and northern California, where it is frequently $75–90^m$ in height.

By far the most successful tree in Flathead valley is western larch. It is a tree that closely resembles its eastern relative (*Larix laricina*) in general appearance, although its habits are decidedly different (*fig. 11*). As already shown, it is one of the first trees to gain a foot-

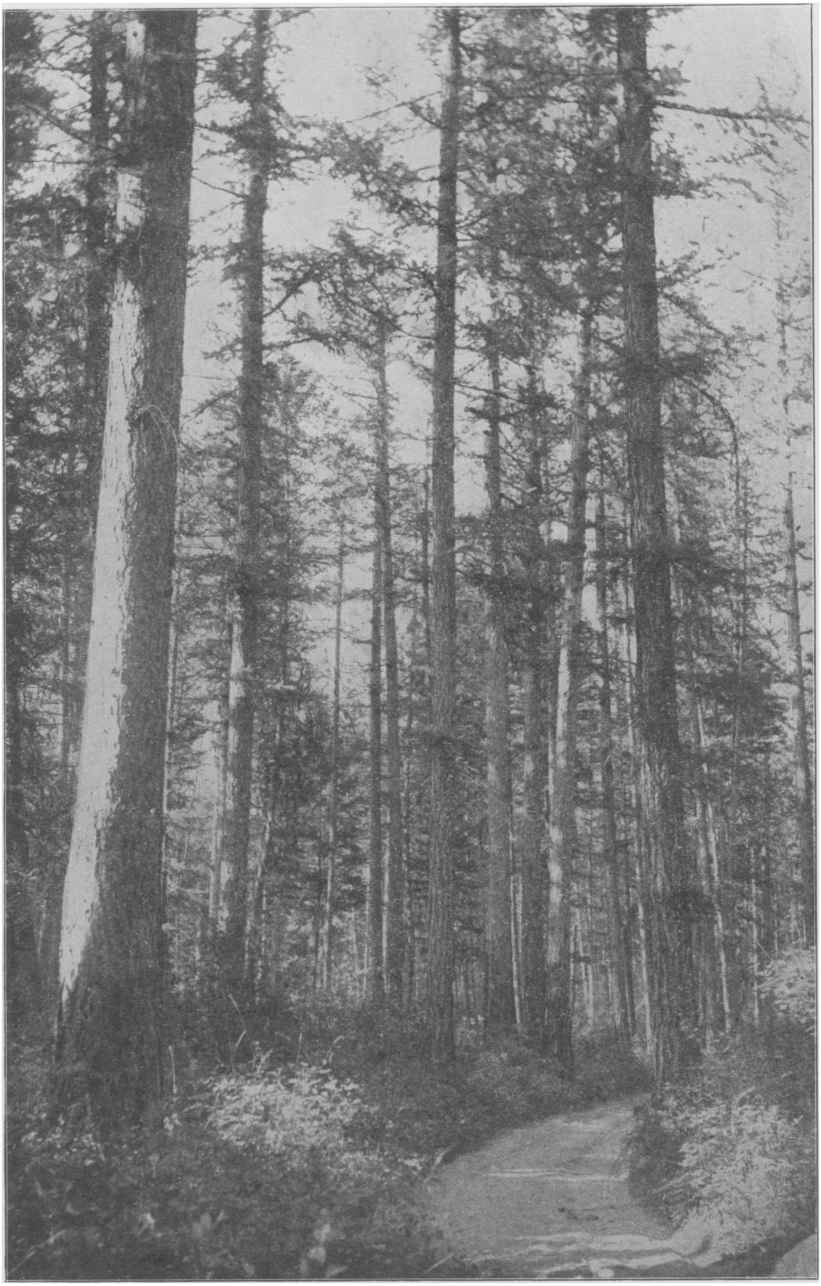

FIG. 11.—View of interior of a western larch-Douglas spruce forest near Big Fork, Montana; the undergrowth consists of *Acer glabrum*, *Philadelphus Lewisii*, *Holodiscus ariaefolia*, etc.—From photograph by McCALLUM.

hold in the spruce association, where it is found on the ridges and hillocks, and it forms an important element in the neighboring forests. There are extensive areas in Swan valley where this is decidedly the predominating species, and on the west slope of the Mission Range in some places there are almost pure stands. It extends out into the prairie regions along the river courses and on protected slopes. It does not grow in as dry soils as Douglas spruce and bull pine, and hence is more restricted in its distribution in regions where the rainfall is slight. The young trees, unlike those of silver pine and lowland fir, cannot endure shade. In no instance was a seedling observed growing in the shade of a forest. Other things being equal, it does best in broad open places, although it can do fairly well in slight openings where the sunlight enters at least during the middle of the day. The western larch then does not tolerate shade and cannot reproduce itself unless an opening be made first in the forest. This may be done in the mature primeval forest by the dropping out of old trees, but more frequently accidents such as fires and winds bring about open places suitable for its reproduction, provided of course seed-bearing trees are left to stock the soil with seeds. In contrast with silver pine and lowland fir, it may be called a fire-resisting tree. Its thick bark enables it to withstand fires that would kill silver pine and lowland fir, old trees often being found still living in the midst of burned areas. Sometimes isolated trees stand towering over the young lodgepole pine growth that has come in after fires (*fig. 12*), and the only young trees competing with lodgepole pines are western larch.

Observations on the rooting habits of trees are in any case difficult to obtain, unless windfalls are frequent. Many trees of western larch were found standing in windfalls where silver pine, lowland fir, and Engelmann spruce had been blown over. From this one would judge that its roots penetrate much deeper than the roots of these trees; indeed this may be one of the reasons why western larch is able to exist in drier areas than can some other trees, for a deep root system will enable it to reach nearer to the underground water level or at least below the superficial dry surface layers where a tree with shallow roots could not get sufficient moisture.

Since Douglas spruce is a successful tree in the regions bordering on the prairie, a discussion of its sylvicultural habits will be deferred until the meso-xerophytic forest is described. It is almost invariably a companion of western larch in the mesophytic area, hence the name western larch-Douglas spruce association.

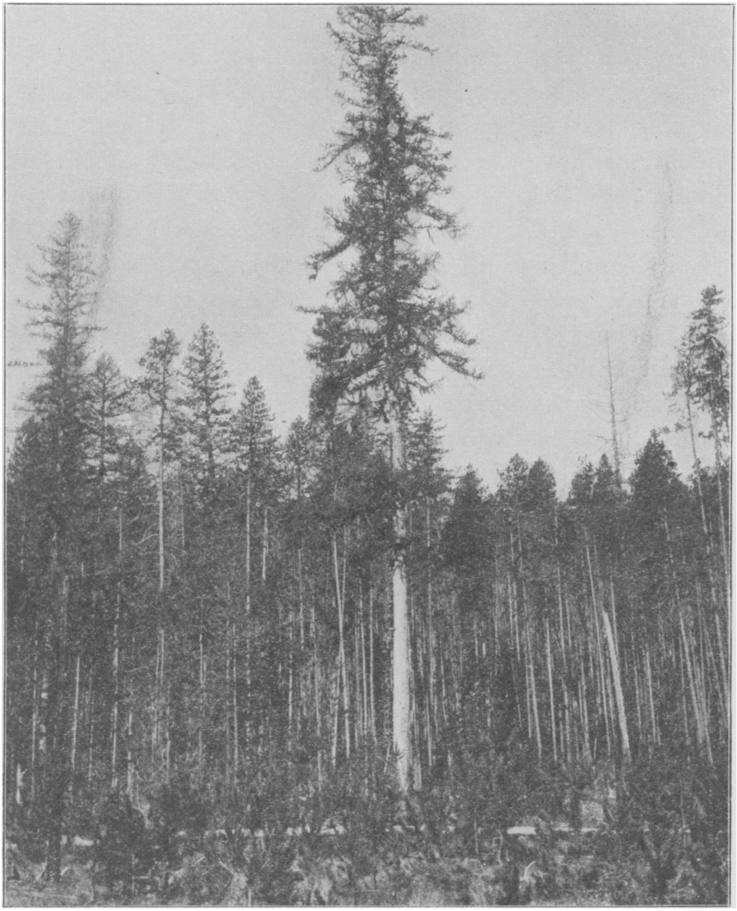

FIG. 12.—Three generations of forests in a "burn" near Ross Lake; first generation represented by isolated old specimens of western larch; second generation consists of a forest of lodgepole pines mixed with a few individuals of western larch; in the foreground is the third generation, which consists almost entirely of young trees of lodgepole pines.—From photograph by PRAEGER.

The giant arborvitae is another tree that needs brief mention here. In the plot under discussion, along the base of the Swan Range there are three isolated places where the arborvitae was noted. It is usually found in moist places and probably ought to be considered as a meso-hydrophytic rather than a mesophytic tree (*fig. 13*). West of the Cascade Mountains, where it reaches its greatest development, it is distinctly a tree of the moister regions.

Another tree found in Swan valley is alpine fir, mentioned before as associated with Engelmann spruce in the moist cañons of the mountains. From here it spreads to the subalpine regions where it occupies a prominent place in the basins where snow lies all the year. In places it also finds its way into the lower altitudes in rather moist situations, as in Swan valley. The birch maintains a place throughout the mesophytic area; especially is it frequent in the moister situations and mixed with the lodgepole forests.

The soil in the mesophytic area is variable in nature, the character of the vegetation changing to a certain extent with the variations. It is probably not the chemical composition that determines the kind of forest, but rather the physical composition, the capacity of the soil for holding water being the controlling factor. If the underground water level is not far below the surface, it makes little difference whether the soil is sand, clay, or gravel, so long as there is sufficient humus to furnish the needed nitrates. However, back from the low-lying lands, where the water level is too far below the surface to be reached by the roots of the trees, the physical character of the soil plays an important rôle. As a rule the soil of the valley is made up of clay, probably derived from the decay of the dolomitic shale, the principal rock of the surrounding mountains. This has been washed in and deposited in the bed of the former more extended Swan Lake, and is mixed more or less with silt. Humus has accumulated in places, and this is more abundant where fires have not been so prevalent; for not only do fires destroy the humus, but in the open places left after the destruction of the forest it dries out rapidly. In contrast with the rich beech and maple woods of the eastern United States, the humus content of the soil is considerably less in these coniferous forests. This is of course due to the fact that the needle leaf of the conifers is not so good a humus producer as the

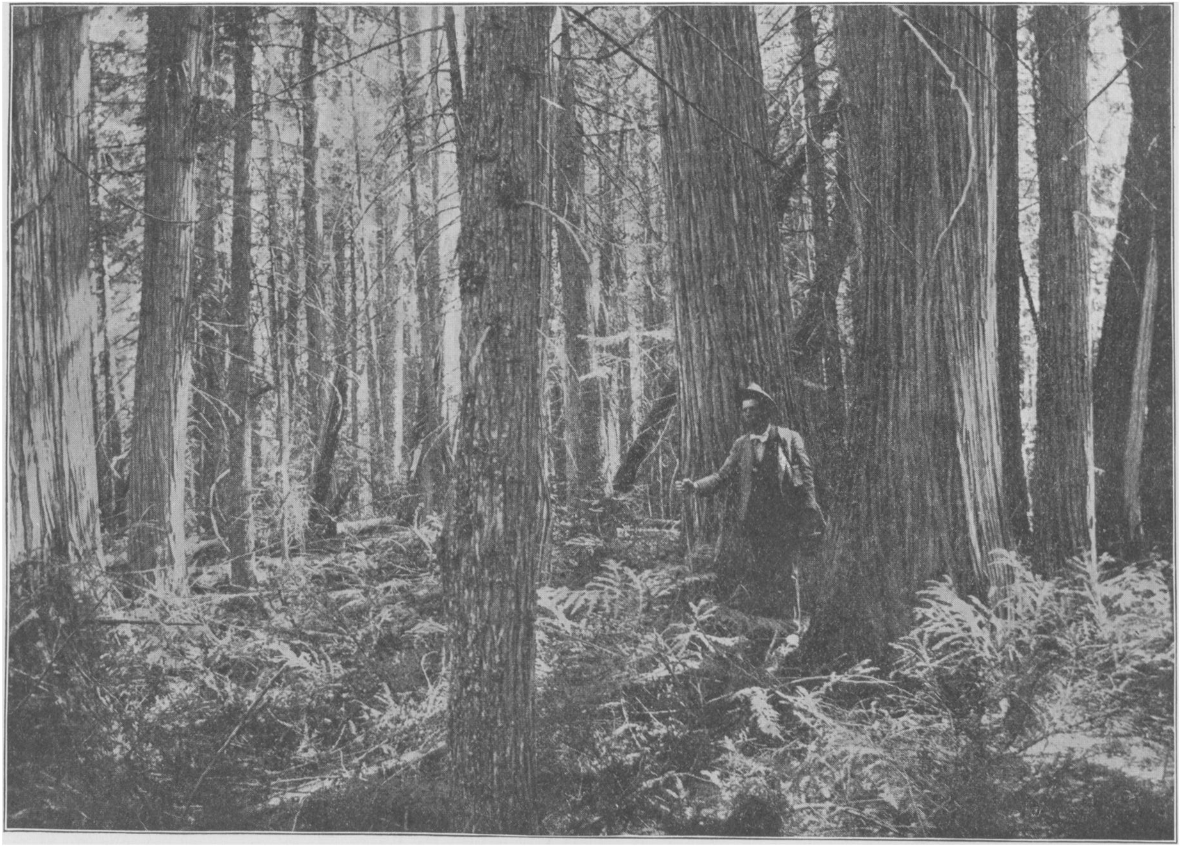

FIG. 13.—Giant arborvitae forest in an inlet of Sinyalcamin Lake, in a part of the Mission Mountains not in the plot mapped; the young trees under the old stand are all arborvitae, as no other species can exist in so dense a shade.—From photograph by HAMILTON.

broad leaves of the maple, beech, and other deciduous trees. In places, however, considerable quantities of humus are present, especially where the trunks of fallen trees have been allowed to decay and have not been destroyed by fire. A very good indication of a soil rich in humus is the number of species of fungi and mycotrophic seed plants found in it; *Monotropa uniflora*, *Pterospora Andromeda*, and *Corallorhiza multiflora* being scattered rather thickly throughout the forest. However, one misses the rich array of fleshy fungi found so abundantly in the leaf mold of the deciduous forests. Except in those places where arborvitae, hemlock, and lowland fir are prominent, the shade is not very dense; and under the rather thin canopy of the other conifers there is enough light to permit the development of a number of semi-shade species.

A woody plant that gives a decided tone to the undergrowth throughout the mesophytic area and to some extent in the meso-xerophytic area is the dwarf maple (*Acer glabrum*), the only representative of the maples found in Flathead valley. It can hardly be called a tree, for it seldom becomes more than 3^{m} in height. Other characteristic shrubby plants are *Salix* sp., *Philadelphus Lewisii*, *Holodiscus ariaefolia*, *Amelanchier alnifolia*, and *Symphoricarpos* sp. In some places, usually more mesophytic, *Menziesia urceolaris* and *Taxus brevifolia* are found. Some of the forms, like snowberry, service berry, and mock orange, become more frequent as the forest becomes more open. Among the prominent more lowly forms were noted the following: *Berberis aquifolium*, *Aralia nudicaulis*, *Cornus canadensis*, *Chimaphila umbellata*, *Pyrola rotundifolia*, *Linnaea borealis*, *Rubus parviflorus*, *Clintonia uniflora*, *Adenocaulon bicolor*, *Tiarella unifoliata*, *Lycopodium* sp., and *Disporum* sp.

At the south end of Swan Lake, on the west side of Big Fork River, is an area with a soil decidedly pebbly, and probably of glacial origin (*map*), its inability to hold water being indicated by the character of the forest it supports. The Douglas spruce is about the only mesophytic tree found here, and in places there are groves of bull pine. On the east side of the river, so persistent is the absence of other species than Douglas spruce and bull pine, that the area was mapped as meso-xerophytic forest rather than mesophytic. It is rather open, and the vegetation in it becomes somewhat prairie-like;

indeed everywhere that the mesophytic forest grades into the Douglas spruce-bull pine combination the forest floor has prairie plants rather than forest forms.

It has been shown that the western larch-Douglas spruce association is found in those areas where the amount of water in the soil is less than in the areas that support the spruce formation. Again, attention must be called to the fact that in the former extension of the lake many parts of the valley now having mesophytic forest were moist enough to support spruce forests, and as the water of the lake receded the amount of water in the soil became less and less until the encroaching mesophytic forests crowded out the spruce forests. As there is a relation in origin, therefore, between the meadows and the spruce forests, so there is also a genetic relation between the spruce forests and the western larch-Douglas spruce forests. In places where the hills end precipitously near the lake shore, as on the west side of Swan Lake for instance (*map*), this relation is not so apparent, for the mesophytic forests reach in many cases to the water's edge. Yet even here narrow, flat areas at the foot of the mountains on the borders of the lake have small meadows with scattered Engelmann spruce and cottonwood in them. These will give way, of course, to the encroaching mesophytic element when the waters of the lake have further withdrawn.

In conclusion it may be pointed out that the climax forest of the plot under consideration is the western larch-Douglas spruce formation. This association occupies a greater portion of the comparatively level stretches of Swan River valley (*fig. 8*). It also is found on the protected slopes and foothills of the low Swan Range. No attempt was made to determine its range outside of the region mapped. The trees that are characteristic of this forest are western larch, Douglas spruce, silver pine, lowland fir, Engelmann spruce, and lodgepole pine.

THE DOUGLAS SPRUCE-BULL PINE (MESO-XEROPHYTIC) AND THE PRAIRIE (XEROPHYTIC) FORMATIONS.

Since the Douglas spruce-bull pine associations and the prairie are more or less connected, they will be treated together. A reference to the map will show that a rectangular plot of ground known as Nigger Prairie lies just north of Swan Hill, at present used for farming purposes. It is bordered on the south, east, and west by narrow strips of pure bull pine forests, and on the north a forest of the same species extends to Echo Lake (*fig. 14*). This bull pine stand is surrounded on all sides by a mesophytic forest in which western larch and Douglas spruce almost entirely replace bull pine.

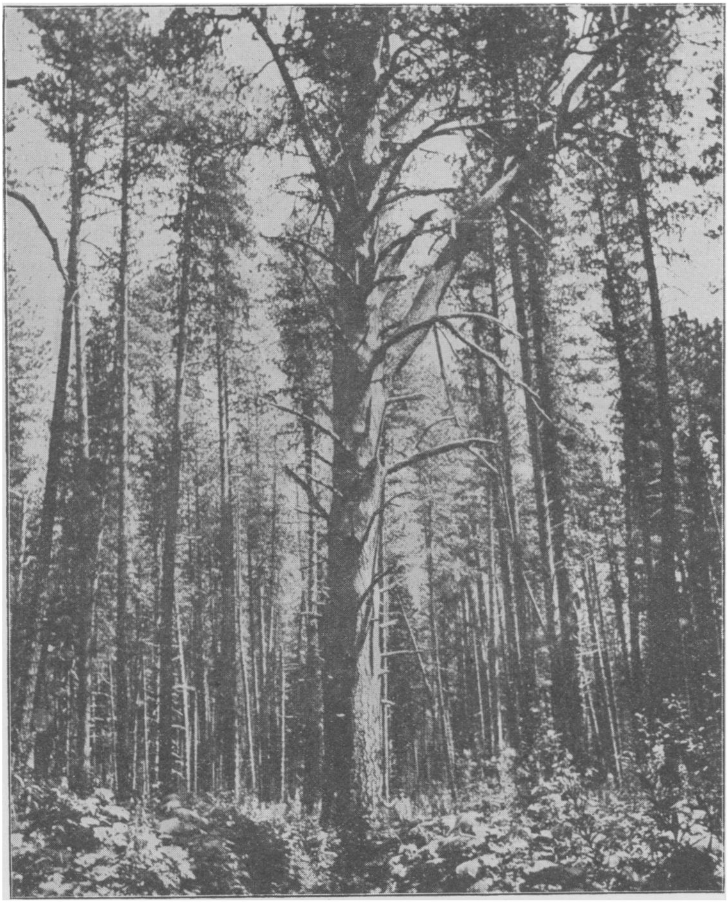

FIG. 14.—View of bull pine forest south of Echo Lake; in the center is a large bull pine, the younger growth around consists of bull pine with some Douglas spruce. —From photograph by PRAEGER.

The question arises, what is the cause of this difference in the character of the vegetation in so limited an area? So far as could be ascertained, trees have been absent from Nigger Prairie for at least twenty years, and it is very probable that it has never been forested.

The character of the soil in both the prairie and the bull pine zone surrounding it is decidedly different from that of the country immediately adjacent. That to the south and west is a residual clay from the dolomite shale of Swan Hill; that to the east is a clay rich in humus; and that to the northwest, north, and northeast is a pebbly clay of glacial origin. On the other hand, the soil of the entire prairie and bull pine region is composed of sand mixed in places with a considerable amount of humus. The limits of this sandy area extend a little beyond the limits of the bull pine forest. It seems very probable that the absence of any other trees than bull pine is due chiefly to the physical character of the soil. It must be remembered that the climate of the area under discussion is such as barely to favor a forest, and a slight difference in the amount of water which the soil can hold may lead to the exclusion of certain trees, and in places of all trees. Since a sandy soil lets water drain through it readily, it is very likely that this area is too dry to support a mesophytic forest. As shown by wells, the underground water level in Nigger Prairie is some distance below the surface, so that those trees which have shallow root systems would not be so likely to succeed as those whose root systems are extensive and deep. The bull pine is one of the latter kind, and it is very likely that this is one reason why it has the habit of growing in drier situations than some of the other trees.

If the surface layers of a sandy soil can be made to retain water, the objectionable feature of such a soil will be partly overcome, and this can be brought about by an accumulation of humus. Lower forms of vegetation, even grass, by their decay will add to the humus content of the soil. In very dry countries this accretion would be exceedingly slow, for the oxidation of the organic débris would be great; but even in dry situations by the accumulation of a slight amount of humus the water-holding capacity of the soil might be increased sufficiently to tide a few trees over the driest months of the year. Trees once established in this way would help accumulate humus more rapidly, for by fall of the dead limbs and leaves more organic material would be added than from the decay of lower forms of vegetation. The shade of the trees thus established would check the rapid oxidation of the organic material that takes place in the open. The ultimate effect would be the establishment of a forest in a place that was formerly occupied by a prairie. It is very probable that the whole yellow pine area just described was at one time occupied by a prairie vegetation. There is evidence that the present prairie island in this forest would become covered with forest trees if not interfered with by man, for along the roadside groups of young growth of bull pine seedlings are not uncommon. All around the border of the prairie young trees are present, and even in a timothy field there were noted seedlings that had escaped being cut by the mowing machine. Before the prairie island was settled it is very probable that surface fires swept it occasionally and thus checked the conquering of the prairie by the forest. Another prairie area similar to the one just described lies directly west of Echo Lake (*map*). Again, west of Nigger Prairie, just across the low range of Mission Mountains, is another "sand pocket" that has a prairie vegetation. These however border on the prairie climate.

The question arises whether the presence of bull pine will in any way change the conditions sufficiently to make them capable of supporting other species of trees. It was shown that the humus content of the soil increases more rapidly when trees are present than when they are absent. With the gradual increment of organic decay, it is very possible that the water-holding capacity of the soil may be increased to such an extent that it will be rendered capable of supporting other species of trees.

A bull pine seedling does not tolerate shade; the young tree must have broad open places where the sun strikes the soil a greater portion of the day. An opening in the forest made by the removal of one or two trees does not allow sufficient light and heat to enter; thus young stands are excluded from anything like a tolerably thick growth of these trees. This is not the case with western larch and Douglas spruce; it has been shown that the former does not tolerate shade, but grows in slight openings in the forest; the latter is very similar in this respect to western larch. If humus has accumulated

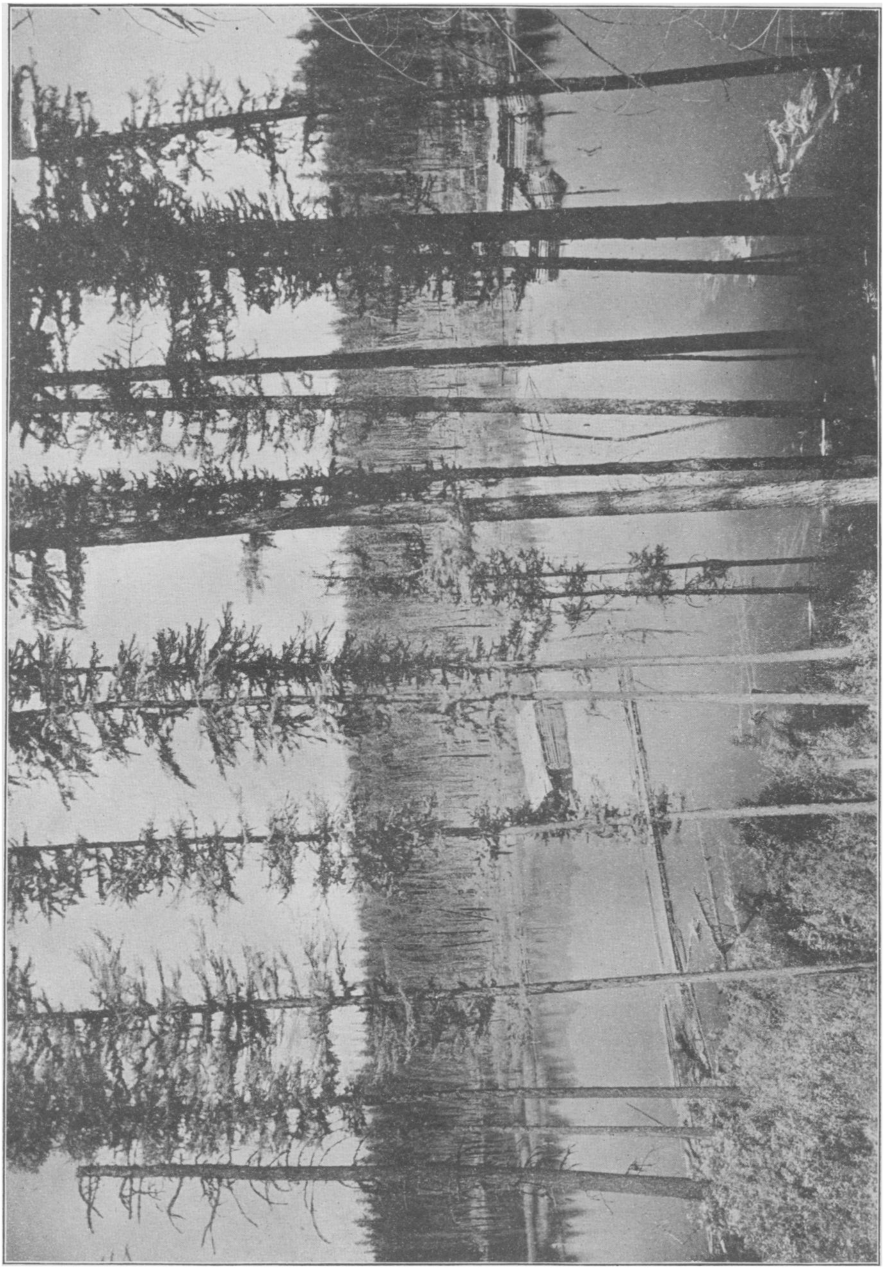

FIG. 15.—View of an arm of Echo Lake, showing submerged cabin and timber land; a few years ago this was dry land; the trees in the foreground are western larch and Douglas spruce.

so as to give the soil a sufficient water-holding capacity, open places in the bull pine forest may permit seedlings of both the species named to thrive. Numerous instances of this were noted in the bull pine forest under consideration. In places where bull pine had been removed there were clumps of young trees of Douglas spruce and western larch. If the place is sufficiently open, bull pine seedlings are found with the others. It will be seen readily that such a condition will lead to a gradual replacement of the bull pine forest by the Douglas spruce-western larch combination. There is some evidence that such a succession has already taken place, for all around the borders of the "sandy pockets" western larch and Douglas spruce are more numerous in places than bull pine. There is also reason to believe that in the pebbly clay morainic soil around Echo Lake, especially to the south and northwest, a more or less pure bull pine stand preceded the present stand consisting of a mixture of the three species. The bull pines are found in groups, or solitary full-grown specimens overtop the younger growths of the next generation of Douglas spruce and western larch, these isolated specimens doubtless representing all that is left of the former pure bull pine stand. Of course this succession has been a gradual one, occupying many generations, the more successful trees elbowing their way, as it were, among the less successful until the spread of the latter is limited by their incapacity to adapt themselves to the new environment. All stages in this succession are present today in the forest under discussion, and it was the study of these stages that led to the conclusion that has been advanced.

Out towards Flathead River the zone between the prairie and the forest contains a few scattered specimens of bull pine; next to this there is a more dense stand of this species with a few scattered trees of Douglas spruce; back farther still from the prairie is a zone in which bull pine is less and Douglas spruce more frequent; and finally another condition is found in which western larch joins these two species, bull pine being the least conspicuous element of the three. Such an arrangement is approximated just west of Echo Lake. This region is decidedly morainic in its character, and where depressions approach the underground water level western larch becomes more numerous, and in places near Echo Lake the surface of these depressions comes near enough to the water level to permit the growth of scattered Engelmann spruce. This level of underground water varies, and this change is shown in the rise of the lake itself and the ponds around it (*fig. 15*).

Mention has already been made of the western larch-Douglas spruce combinations on the protected slopes of the Mission Mountains. Toward the top of this slope western larch becomes less and Douglas spruce more prominent; in places the latter is mixed with lodgepole pine. On the west side of the range Douglas spruce and bull pine are the principal species; hence this area has been mapped as meso-xerophytic, although western larch is present in some situations.

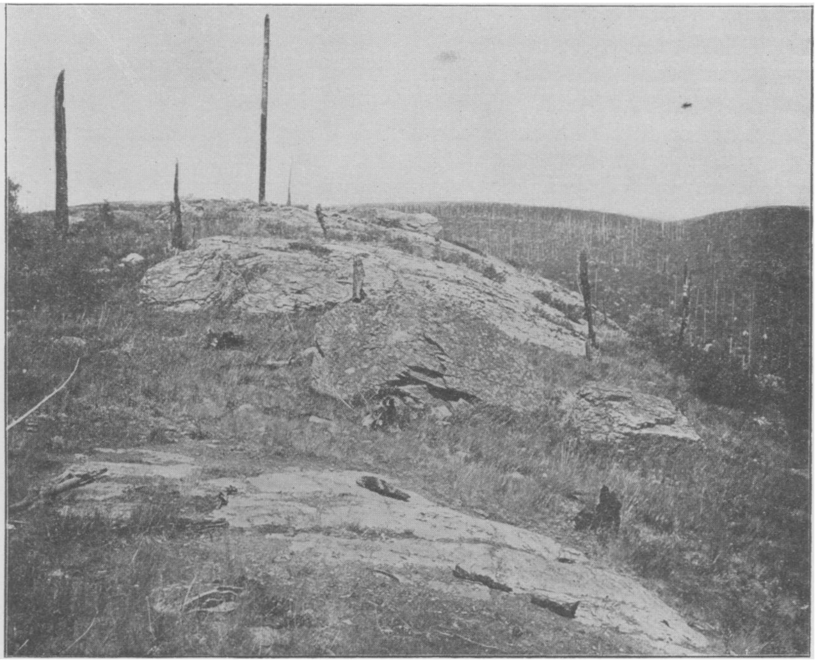

FIG. 16.—View on the top of the Mission Mountains showing area on which the Douglas spruce-bull pine forest has been destroyed by fire; the outcrop of dolomitic shale has been scoured smooth by the action of glacial ice; Ceanothus bushes on the right, lichens of various sorts on the rocks, and prairie grasses where the soil is sufficiently deep.—From photograph by PRAEGER.

The altitude of the Mission Range within the limits of the plot is nowhere more than 1372^{m} above the level of the surrounding country. The core of the mountains is composed of a dolomite shale, which outcrops in many places. Especially is the rock near the surface on the steep northwest fault face and where the soil has been removed by the action of glaciers (*fig. 16*). South of the river the forest on the western slope has been partially destroyed by fire (*figs. 16* and *17*), but enough of the original stand remains to give a clue to the conditions of the whole slope. A discussion of the burned area will be taken up in another connection.

Wherever the rock outcrops there is little or no vegetation (*fig. 16*), due to the fact that there is no soil; the pioneer plants on the rocks here, as elsewhere, are the lichens. The crustaceous lichens appear where there is absolutely no disintegrated rock; sometimes associated with these are the foliaceous forms, but these are more common where a little soil has accumulated; with these are found mosses adapted to the dry conditions. After more soil has accumulated, conditions are favorable for plants that require more moisture; among these are the fruitcose lichens, *Cladonia rangiferina sylvatica* being a good example. Associated with these lichens are *Selaginella densa*, *Sedum Douglasii*, *Heuchera parvifolia*, the last being usually found rooted in cracks. These plants prepare the way by their decay for the higher forms that can get a foothold as soon as sufficient soil is present. The inorganic material made by the disintegration of the rocks is blown or washed in from the surrounding region and reinforces the organic accretion. In the meantime the rock crevices have been filling up with soil, thus furnishing favorable places for shrubs like *Prunus demissa*, *Symphoricarpos* sp., *Amelanchier alnifolia*, and *Juniperus sibirica;* and *Campanula rotundifolia*, *Arctostaphylos Uva-ursi*, and grasses are early pioneers in these places. If the outcrop is near a large body of water like Flathead Lake, *Juniperus scopulorum* is one of the first trees. This tree is found distributed around the shores of the lake and along water courses in the prairie region in the valley at the foot of the lake, and with it are found Douglas spruce and bull pine. These of course gain a foothold by sending their roots into the rock crevices and may play an important rôle in the weathering processes by prying the rocks

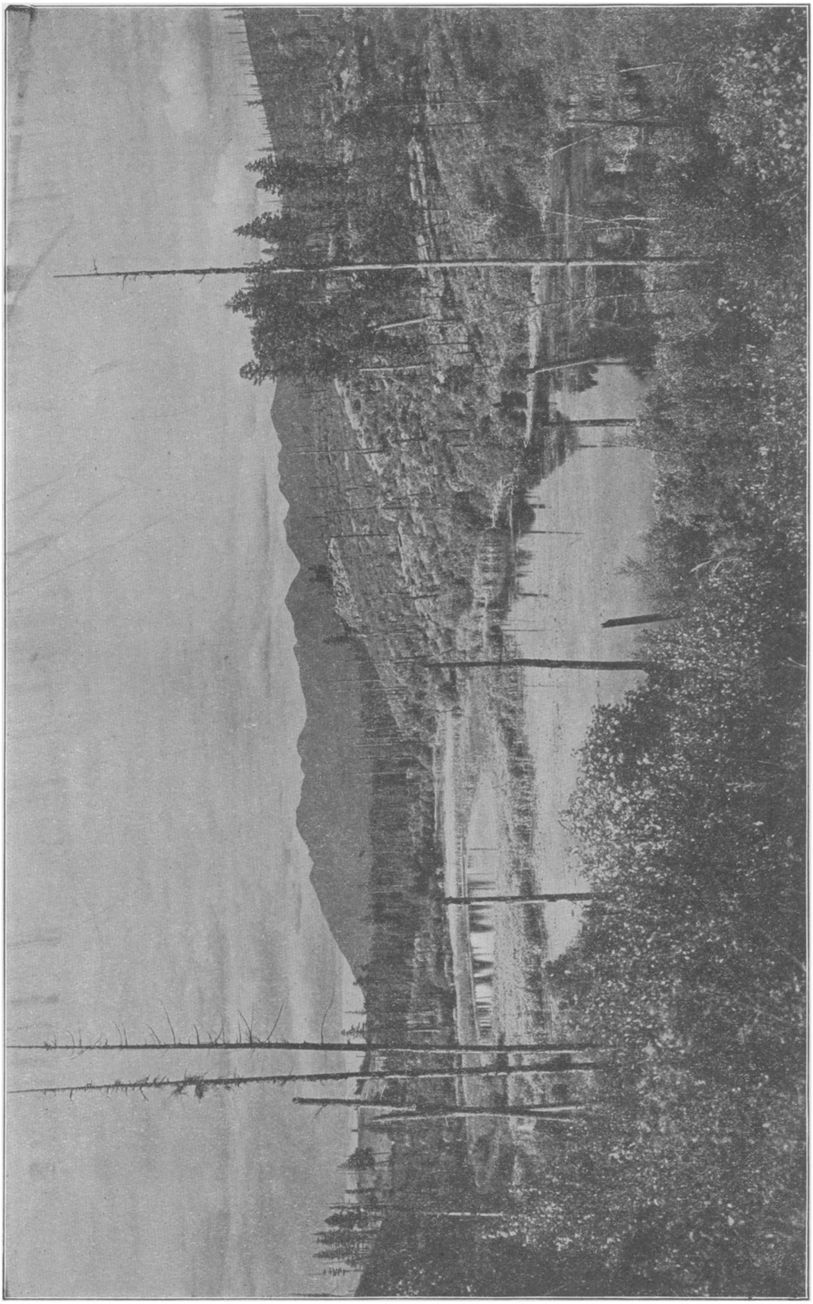

FIG. 17.—View of burned region on west slope of Mission Mountains; Daphnia pond nearly filled with hydrophytic vegetation; the forests of larch, Douglas spruce and bull pine almost entirely destroyed; the bushy growth that becomes vigorous after the forests have been destroyed is Ceanothus, Amelanchier, Salix, etc.—From photograph by ELROD.

apart in the growth of their roots. However, on the rocks there is never more than a scattered growth of trees. Where the soil is less shallow, more trees are present and a more closed stand is developed. In the ravines and other situations where a deep soil has accumulated, a heavy growth often occurs; especially is this true in the protected ravines and on the sheltered slopes. Along the front of Flathead Lake there is a series of ridges which has an open growth of Douglas spruce and bull pine on the side facing the lake; and protected from winds, the slopes on the east side of these ridges and the valley between them and the higher ridges to the east have in addition western larch, which in places is the dominant tree. Again, where the surface of this valley is not far above water level, Engelmann spruce and its associates are found, though these places are infrequent. In many protected areas on the west side of the Mission Range western larch is present, though as contrasted with the eastern slope the exposed western face of the mountains is not so favorable a habitat for the mesophytic trees.

The temperature conditions on top of these mountains and at the foot are not known. No doubt the climate is considerably cooler at an altitude of 1372^{m}, the highest point of the range in the plot, than it is at 890^{m}, the level of the lake. However, this difference is not enough to exclude the lowland species and introduce those found on the higher Swan Mountains to the east. The presence of a large body of water like Flathead Lake no doubt influences the temperature conditions along its shores, for early fall frosts are less frequent here than at a short distance inland. Whether or not this affects the forest growth is not known.

[*To be concluded.*]